6. Distribution Network & Devices

Needs to Know Criteria
▪ Flow meters, pump run timers, and run counters
▪ Backflow prevention assemblies
▪ Role of a pipe cleanout
▪ Types of irrigation systems
▪ Types of irrigation application devices
▪ Maintaining plans or maps of wastewater land application components and piping
▪ Irrigation system performance when operating pressure differs from design pressure
▪ Steps to take if actual flow exceeds the system design flow

This section addresses the equipment used to pump and distribute wastewater to the land application site. In most cases, operators will be operating and maintaining equipment and systems that were chosen and designed by someone else. Operators will have greater success in operating and maintaining a distribution system that was properly designed and installed, but even good design does not guarantee that wastewater will be properly applied: poor operation can adversely affect the performance of a well-designed system.

Conversely, careful operation of a poorly designed system can sometimes provide good performance. Therefore, operators of wastewater land application systems need a basic understanding of pumps and their controls as well as an understanding of distribution networks and their devices.

6.1 Pumps and Controls

A pump is a mechanical device that imparts energy to liquids to move the liquids from one location to another. All pumps operate on the following principals:

- air is exhausted from the working chamber
- atmospheric pressure then forces water (or another liquid) into the chamber
- the pump mechanism forces the water out of the chamber, creating a partial vacuum
- additional water fills the chamber to repeat this cycle

General Concepts

Before discussing specific types of pumps, it is important to understand the following general concepts:

- pump head
- horsepower
- pump capacity

- pump performance curves

Head

Pumps are designed to deliver liquid against a specific pressure. Water has a specific weight (62.4 pounds per cubic foot or 8.34 pounds per gallon), and this weight resting on a surface exerts a force on that surface. Force on a specific area is called pressure. Pressure is the total load or force acting on a surface, and is usually expressed in terms of pounds per square inch or pounds per square foot. Pressure can also be expressed in terms of feet of water, for its origin is the weight of a depth of water directly resting upon the area of measurement.

When pressure is measured in feet, it is called *head*. Pump head is defined as the resistance against which a pump will operate. A water column 100 feet high will exert a pressure of approximately 44 pounds per square inch. Conversely, 1 pound per square inch of pressure is equivalent to 2.31 feet of head.

In most cases, pumps are installed to provide the pressure necessary to move water from one location or elevation to another in a wastewater treatment system. Since the function of a pump is to add pressure to the system, the pressure on the discharge side of the pump will always be higher than the pressure on the suction side of the pump. In pump systems, measurements are taken from the point of reference to the centerline of the pump. Pump heads include both *static head* (when the pump is off) and *dynamic heads* (when the pump is on).

Horsepower

To purchase the appropriate pump for the job needed, it must be determined how much work the pump will be required to do and the rate at which the work will be done:

- *Work* is the operation of a force (pressure times area) over a specific distance, expressed in units of foot-pounds. One foot-pound is the amount of work required to lift a one pound object one foot off the ground.
- *Power* is the rate at which work is being done, and it is expressed as foot-pounds per second. Large units of power are called *horsepower*. One horsepower is 550 foot-pounds per second.

Motor, brake, and water horsepower are terms used to indicate where the horsepower is measured (Figure 6-1). Pumps are driven by motors, which are never 100% efficient; most motors are usually 80 to 90% efficient. *Motor horsepower* (mhp) is the horsepower applied to the motor in the form of electrical current. A portion of this horsepower is lost due to the conversion of electrical energy to mechanical energy.

Like motors, pumps are also not 100% efficient. *Pump efficiency* is the power produced by the unit, divided by the power used in operating the unit. Most pumps are 60 - 85% efficient.

Brake horsepower (bhp) is the horsepower applied to the pump, or the power delivered to the pump shaft by the motor. Due to friction and slippage losses, more power is lost as the power moves through the pump.

Water horsepower (whp) is the actual horsepower available to pump wastewater.

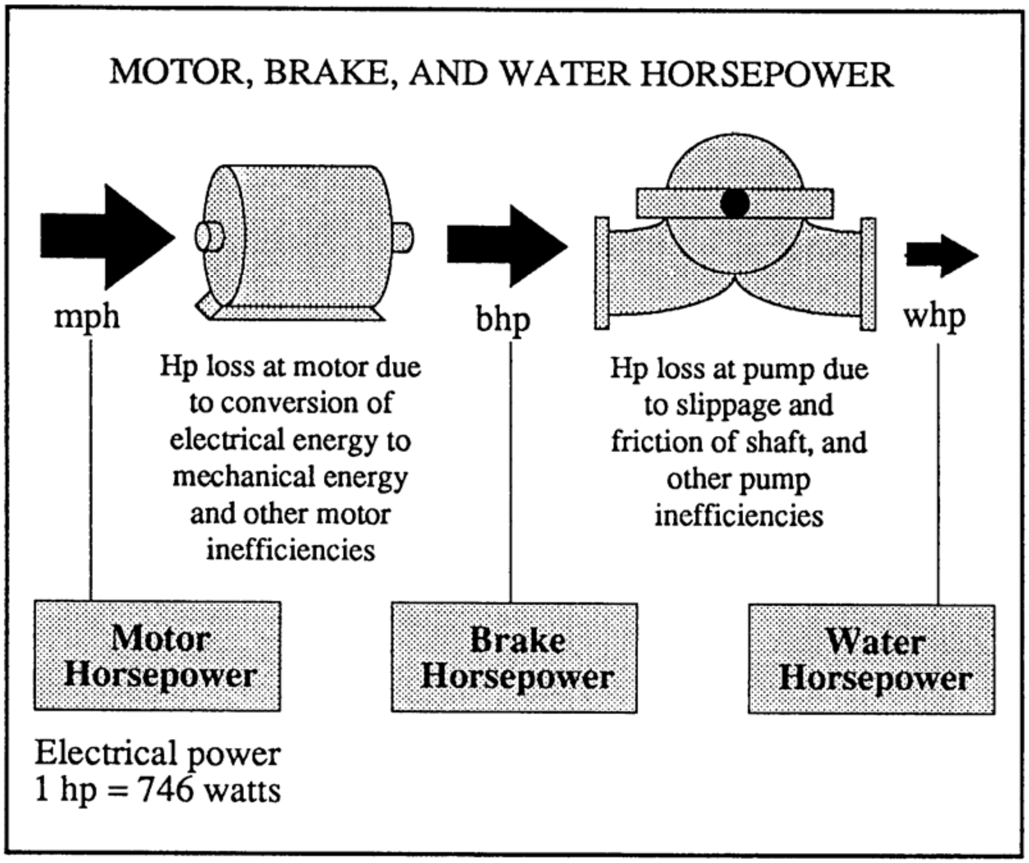

Figure 6-1.Motor, brake and water horsepower. [from Applied Math for Wastewater Plant Operators, 1991]

Motor, brake, and water horsepower can be calculated as follows:

$$\text{mhp} = \frac{\text{brake horsepower}}{\text{motor efficiency}}$$

Equation 6-1. Calculation of motor horsepower.

$$\text{bhp} = \frac{\text{water horsepower}}{\text{pump efficiency}}$$

Equation 6-2. Calculation of brake horsepower.

$$\text{whp} = \frac{\text{head (ft)} \times \text{flow (gpm)}}{3960}$$

Equation 6-3. Calculation of water horsepower.

Pump Capacity and Pump Delivery Rates

Each pump is designed to deliver a designated amount of flow against a specific head. This is the *design pump capacity* or *design pump delivery rate* (gpm). However, actual pump capacity or delivery rates can vary, depending on the efficiency of a pump and the conditions under which it is operated.

The pump capacity and quantity of flow, in turn, determine the time required for each pumping or dosing cycle and the length of time between cycles. The amount of wastewater pumped to a land application field during a pump cycle is called the *dosing volume* (in gallons). The *pump delivery rate* is the amount of wastewater pumped during a pump cycle divided by the pump run time (in minutes). The *pump delivery rate efficiency* is the measured pump delivery rate (in gallons per minute) divided by the design pump delivery rate times 100%. These calculations are discussed in Section 10.

Pump Performance

Pumps can deliver a wide range of flows, depending on design, speed, and total dynamic head. The best source of information on a particular pump is the manufacturer's pump performance curve, which provides information on discharge (flow), power requirements, and head characteristics.

Each pump is manufactured to operate most efficiently at a designated amount of head and flow. Operating a pump as close to peak efficiency as possible allows it to operate with the least amount of strain possible. Operating a pump well off peak efficiency can result in excessive energy requirements and shortened pump life.

To better understand the performance and operating characteristics of pumps, operators should become familiar with the pump curve that is supplied by the manufacturer for each pump. A pump curve shows the relationships between pump head, flow, efficiency and horsepower. Pump curves can be used in case you need to modify your operating conditions from the original irrigation design. This may be necessary, for example, if you discover that the actual flow (discharge) exceeds the system design flow. A typical pump curve is shown in Figure 6-2.

Pump curves usually show three curves on one sheet:

- The *head-capacity curve* shows the discharge in gallons per minute (gpm) the pump will deliver against various heads when operated at the proper speed. This curve shows that as the head increases, the discharge decreases, until there is no further discharge. Conversely, as head decreases, flow increases.
- The second curve, also plotted against flow, shows the *efficiency* at which the pump operates at various points on the head capacity curve. This curve shows that no pump is 100% efficient, due to internal friction losses. The highest efficiency that can be hoped for is around 85%. Efficiency can be expected to decrease with age and wear.
- The third curve, the *brake horsepower curve*, shows power consumed plotted against flow. If we know the total head at which the pump is operating, we can use the curve to find the gallons pumped. The power required by the pump, as well as the pump efficiency, can also be read from the curve for any set of conditions. This curve shows that it usually takes more horsepower to pump more water: the lower the flow, the lower the horsepower required, and the higher the flow, the higher the horsepower required.

As discussed earlier, a pump operates most efficiently at the flow and head it was designed and rated for. This is sometimes called the *design point* or *best efficiency point*. This point normally falls in the middle of the pump performance curve. Operation at either extreme of the curve should be avoided. Operating a pump below the manufacturer's specified minimum head (at the high flow end of the curve) can result in overloading the motor. Operating a pump in the extreme high head region of the curve can result in decreased efficiency, increased noise and vibration, and low flows.

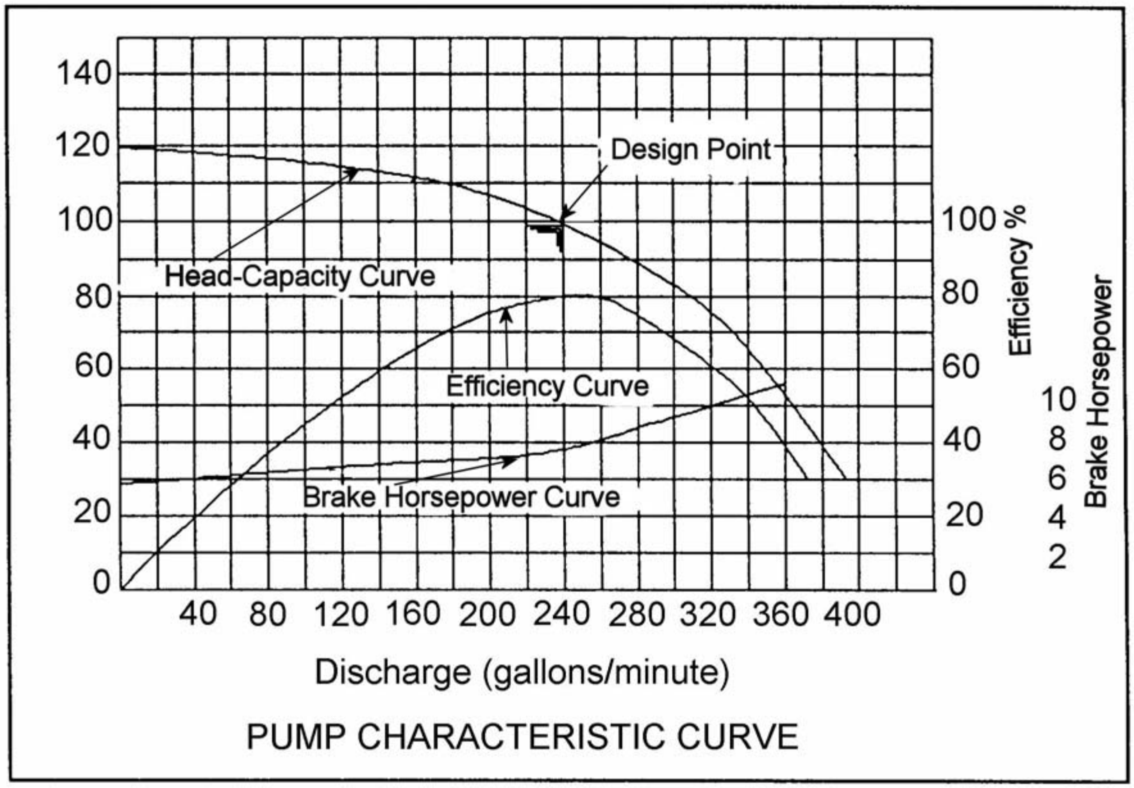

Figure 6-2. Pump characteristic curve (modified from Hauser 1991].

Pumps

There are a variety of pumps that you may encounter at your land application facility. Brief descriptions of some common pump types are provided below.

Centrifugal Pumps

Centrifugal pumps are radial flow pumps that can be used for most wastewater pumping activities. They consist of one or more impellers rotating in a casing, or *volute*. Impellers may be of the open, semi-open, or closed type. Open impellers are normally used for wastewater applications while closed impellers are normally used for irrigation waters that are relatively clean. Centrifugal pumps generally have a maximum suction of 34 feet. The practical suction is generally 20 feet or less.

Turbine Pumps

Turbine pumps are basically centrifugal pumps that are stacked on top of each other. Turbine pumps may have up to 25 stages, depending on the type of impellers used. Each stage adds pressure, not volume. They are generally used for deep well irrigation systems or other applications where the intake is below the

the liquid level and where high discharge pressures are needed.

Submersible Pumps

Another type of centrifugal pump is the submersible pump. Submersible pumps are vertical, heavy-duty centrifugal pumps designed to work while immersed in the water that they are pumping. The watertight motor is also submerged. The surrounding water helps cool the pump and motor, extending their life and efficiency.

Reciprocating, Piston, or Plunger Pumps

Positive displacement pumps are usually associated with wastewater that contains high levels of solids, and they must be operated with an open discharge valve. One such pump is the reciprocating pump. A reciprocating pump (also called a *piston* or *plunger* pump) moves wastewater or sludge by a piston or plunger that moves back and forth. This movement forces wastewater from the suction side to the discharge side of the pump.

Because the movement of the plunger or piston creates pressure inside the pump, this kind of pump should never be operated against a closed discharge valve. To prevent a build-up of pressure that could damage the pump or burst pipes, all discharge valves must be open before the pump is started. Because force is exerted during the suction cycle also, the suction valve too should be always left at least partly open.

Diaphragm Pumps

Another type of positive displacement pump is the diaphragm pump, often used for chemical feed. Instead of using a piston or a plunger, a diaphragm (a flexible membrane) is used to force wastewater from the suction to the discharge side of the pump. In a diaphragm pump, wastewater does not come in contact with moving metal parts, an advantage over the reciprocating pump. This can be important when pumping abrasive or corrosive liquids.

Peristaltic Pumps

Peristaltic pumps are used for wastewater sampling or chemical feed. Peristaltic pumps, the oldest pumps in existence, are another type of positive displacement pump. Wastewater is moved through flexible tubing by advancing rollers that squeeze the tubing Nothing but the tube touches the wastewater, thus eliminating any risk of contamination. Pump design prevents backflow and siphoning without valves.

Pumping System Components

Pumping system components include the pump itself, electrical connections to a motor, a shaft to drive the pump, a seal between the water chamber and the motor, an impeller with inlet and outlet ports, and a mounting stand. Rail systems are recommended, when using large submersible pumps, to access pumps for repair or replacement.

Bearings

There are several types of bearings used in pumps, such as ball bearings, roller bearings, and thrust bearings. Each bearing has a special purpose. The type of bearing used in each pump depends on the manufacturer's design and application.

Bearings are machine parts designed to reduce friction between moving parts or to support moving loads. There are two main kinds of bearings:

- antifriction type, such as the roller bearing and the ball bearing, operating on the principle of rolling friction.
- plain or sliding type, such as the thrust bearing, employing the principle of sliding friction; thrust bearings are used to support the pump shaft.

Pump bearings should last for years if serviced properly and used in their proper application. Whenever a bearing failure occurs, the bearing should be examined to determine the cause and, if possible, eliminate the problem. Many bearings are ruined during installation or pump startup.

Packing

Pump packing reduces or eliminates internal liquid leakage within a pump. This is important because the objective is to pump water, not air, and because air leakage can cause a pump to lose suction. To keep air from being drawn into the pump, *stuffing boxes* are used. Each stuffing box consists of casing, rings of packing and a gland at the outside end. Each ring of packing should be placed separately and seated firmly before adding the next. These rings are removable and replaceable when wear enlarges the tiny gap between them and the impeller.

In addition to increasing the efficiency of the pump by reducing air leakage, pump packing can prolong the life of the pump and shaft by reducing friction. The manufacturer's recommendations should be followed in choosing a packing.

Mechanical Seals

Many pumps use mechanical seals in place of packing. Mechanical seals serve the same purpose as packing: they prevent leakage between the pump casing and shaft. Like packing, they are located in the stuffing box where the shaft goes through the volute; however, they should not leak.

Mechanical seals have two faces that mate tightly and prevent water from passing through them. One half of the seal is mounted in the pump or gland with an "O" ring or gasket, thus providing sealing between the housing and seal face. This prevents water from going around the seal face and housing. The other half of the mechanical seal is installed on the pump shaft. This part also has an "O" ring or gasket between the shaft and seal to prevent water from leaking between the seal part and shaft. There is a spring located behind one of the seal parts, which applies pressure to hold the two faces of the seal together and keeps any water from leaking out. One half of the seal is stationary, and the other half is revolving with the shaft.

Some of the advantages of mechanical seals are as follows:

- they last from three to four years without one having to touch them, resulting in labor savings

- usually there is no damage to the shaft sleeve when they need replacing
- continual adjusting, cleaning, or repacking is not required

Some of the limitations of mechanical seals include the following:

- high initial cost
- competent mechanic required for installation
- when they fail, pump must be shut down
- pump must be dismantled to repair

Lubrication

Pumps, motors and drives should be oiled and greased in strict accordance with the recommendations of the manufacturer. The best quality oils and grease obtainable should be used. Over-greasing should be avoided, as too much grease will cause as much damage as lack of lubrication. It is especially important not to over-lubricate motor bearings as this can lead to bearing seal failures. This has been the cause of an untold number of motor failures. The present trend is toward the increased use of sealed bearings that require no additional grease for their lifetime.

Priming a Pump

A pump will not operate unless it has been properly primed. A pump is considered primed when the pump casing and the suction piping are completely filled with liquid. A pump that has a positive suction head will seldom lose its prime, whether the pump is on or off, and will likely only need to be primed after it has been opened or replaced.

For pumps with a negative suction head (suction lift), the water tends to run back out of the pump and down the suction line when the pump stops. If the casing is filled with air, the impeller cannot create enough vacuum upon starting to draw water back into the unit, and the air will just circulate around in the pump. In this situation, both the pump and motor will overheat in a short time. If a positive suction head cannot be provided, the pump must be separately primed (filled with water) each time it is started unless it is equipped with some type of self-priming device, such as a foot valve, a vacuum pump or ejector, or a priming chamber.

Cavitation

Cavitation is the formation and collapse of a gas pocket or bubble on the blade of an impeller. This condition results from unusually low pressures that can occur when pump inlet pressures drop below the design inlet pressures or when the pump is operated at flow rates considerably higher than design flows. Cavitation is accompanied by loud noises that sound like someone is pounding on the impeller or valve with a hammer. Damage caused by cavitation can be severe, resulting in replacement of the impeller or the impeller and volute.

Water Hammer

Also known as hydraulic shock, *water hammer* is an oscillation in pressure that results from a too rapid acceleration or retardation of flow, such as when a valve is opened or closed very rapidly. When a valve position is changed quickly, the water pressure in a pipe will increase and decrease back and forth very quickly. This rise and fall in pressures can cause serious damage to the system as well as producing a noise that sounds like someone hammering on a pipe.

Surge tanks installed in the areas where water hammer is a problem can absorb some of the pressure.

Air release (sometimes called air relief) valves can also help minimize water hammer damage. These devices allow the release of air in the distribution network while the system is pressurizing. These valves are usually installed at high elevation points in a distribution network, as well as at the end of laterals and trunk lines where air might be forced to a dead end.

Pump Controls

A variety of controls are used to operate wastewater pumping systems. These controls are used to activate pumps, valves, water level sensing devices, alarms, timers, counters, and meters. Controls are contained in protected enclosures, called *control panels*. Control panels can be *simplex* (control one pump), *duplex* (control two pumps), or *multiplex* (control more than two pumps). All control panels should have a ground rod and a *hand-off-automatic* (HOA) switch that allows the operator to override the control system and manually activate the pump. Panels should have visual and audible alarms and an alarm silence switch.

Water Level Sensing and Pump Control

Accurate sensing of high and low water levels is critical for proper timing of pump operation. Control of pumping systems is achieved by an ON/OFF type of control, which starts and stops pumps according to a level, pressure, or flow measurement.

Usually an ON/OFF pump control system responds to level changes in a tank of some type. Water level can be sensed directly with a float or by a pressure change at the tank or pump site. The pump is thus turned off or on as tank level rises above or falls below predetermined level or pressure limits. These controls can either be single-point detection or continuous detection.

Other possible pump controls include turning the pump OFF if there is a loss of the level signal or low suction pressure.

Types of ON/OFF pump controls include the following:

- float switches
- pressure bulbs and diaphragm switches
- bubble tubes
- electrode switches
- ultrasonic sensors

Alarms

Alarms are visual and/or audible signals that indicate a variable is out of bounds, or that a condition exists in the system requiring the operator's attention. They can vary from a simple high water level alarm to a multiple system. The most common and necessary is the high water alarm. High water alarms can be activated using the same ON/OFF controls used to sense water level changes. Other alarms that may be necessary include pump failure alarms, power failure alarms, seal failure alarms, and motor head sensor alarms.

Timers are devices that allow an operator to control pumps or controls in specified ways at predetermined times. *Run cycle timers* are timers that repeatedly open and close contacts according to preset time cycles while pump run timers are timers that are helpful in calculately the volume of wastewater being discharged.

Counters

Counters provide flow indication for timer panels. A counter can be used to add up the number of times the pump has been activated. Or, in the case of run counters, used to calculate the volume of wastewater being discharged.

Telemetry

Telemetry is the automatic transmission of data on wastewater system characteristics between two widely separated locations, typically an isolated, unattended facility and a central, attended facility. Telemetry provides an electrical link between a field transmitter and the receiver. Telephone lines are commonly used to serve as the electrical line.

Microprocessors

Microprocessors and computers are now commonly used in many wastewater applications, including individual instruments and entire digital computer-based control systems. Microprocessors can do extremely complex functions at high speeds with low power consumption. The most significant example of the utility of the microprocessor is the personal computer (PC). These microprocessors are relatively inexpensive, stand-alone computer systems that can help an operator enter, store, retrieve, and manipulate enormous amounts of data quickly and easily.

Meters

Meters are instruments for measuring some quantity, such as the amount or rate of wastewater flow. It is necessary to know the wastewater flow rate in a pretreatment system so that adjustments can be made to pumping rates, chlorination rates, and other processes in the system. Wastewater flow rates must also be known for calculating hydraulic loadings and constituent loadings at a wastewater land application site.

Elapsed time meters are used to record the amount of time each pump runs. This is a good way to monitor the hours per day that a pump runs. One elapsed time meter is used per pump. If a flow meter is not installed or operational on the wastewater discharge line, operators may use a combination of pump run timers, knowledge of the operating characteristics of the pump, and the manufacturer's pump performance curve to estimate the flow of applied wastewater.

Flow measuring devices must be periodically calibrated to ensure their continued precision and accuracy. Most manufacturers and dealer representatives will offer a service and maintenance agreement with a flow meter for its periodic calibration. Calibration is recommended once per year.

Comparing flow measurement against other methods of flow estimation can also help to calibrate pump discharge rates. For example, total flow in a pump cycle may be estimated by knowing the discharge rate from a sprinkler based on nozzle size and pressure (which gives gallons per minute) and multiplying this value by the total pump run time.

Another standard to check against is pump *drawdown* in a tank or wet well, or lagoon level drawdown. To estimate flow rate by the pump drawdown method, the influent flow into the tank or lagoon must be valved-off or precisely measured.

An operator should use all appropriate techniques to help with flow management and calibration for a wastewater land application system.

6.2 Distribution Network and Devices

To ensure the appropriate amount of wastewater is uniformly applied at a wastewater land application site, operators must be familiar with common types of irrigation application devices (sprinklers), irrigation system design, correct pressure settings, and other distribution system operating issues. This section discusses distribution system components and general operational procedures for common types of wastewater irrigation systems.

Pipes, Fittings, Connections, and Valves

Pipes

A piping system consists of the pipes, fittings, and appurtenances within which a fluid flows. Before discussing specific types of pipes, we need to define some terms that will be used in our discussion of piping:

- OD - outside diameter.
- ID - inside diameter.
- IPS - iron pipe size.
- PIP - plastic irrigation pipe size.
- Class - a pipe's pressure rating (PR).
- SDR - Standard Dimensional Ratio number; the outside diameter divided by the minimum wall thickness; the larger the SDR number, the thinner the wall is in the pipe.

- NPT - nominal pipe thread

Piping used in wastewater land application systems can either be made of concrete, metal (iron, stainless steel, copper, aluminum) or plastic (PVC or *polyethylene*). Several of these are discussed below:

- **Concrete -** Concrete pipe is primarily used for large diameter lines. The most common type of concrete pipe is manufactured by wrapping a wire around a steel cylinder and using a cement coating to cover the steel cylinder both internally and externally. This pipe is made to withstand internal pressures up to 300 pounds per square inch (psi) and can be placed in trenches up to 70 feet deep. Concrete pipe is very resistant to corrosion except in very low pH waters. The cement mortar is the protective agent for the steel cylinder; therefore, the pipe must be handled with care. Damage to the cement mortar either internally or externally will subject the pipe to corrosion. Advantages of this material are its ability to withstand high external loads and corrosion. Major disadvantages are its weight and the care with which it must be installed.

- **Cast Iron -** Cast iron pipe is some of the oldest piping material in use today. It is now manufactured by a process called *spin casting*, during which molten iron is injected into a spinning mold. The result is a pipe of consistent diameter and wall thickness. Cast iron pipe can withstand high working pressures. Pressure ratings of 350 psi are common. However, the material cannot withstand sharp shock loads either internally or externally.

- **Steel -** Steel pipe is made by extruding or welding sections of steel to form a pipe. This pipe falls into two categories: *mill pipe* and *fabricated pipe*. Steel pipe is classed as a flexible conduit, meaning that it has the ability to withstand a 3% deflection of the diameter without damage to the pipe. Steel pipe is commonly manufactured to meet very high pressures (up to 700 psi is not uncommon). However, under a vacuum it will collapse. Because steel pipe is a flexible conduit, it requires a selection of wall thickness suitable to withstand external loads as well as internal loads. Steel can easily be shaped into various sizes and shapes, which is one of its major advantages. It also has a high tensile strength and high ductility. These characteristics give it the ability to withstand high internal and external loads. The main disadvantage of steel pipe is that it is easily attacked by corrosive elements, which results in high maintenance costs. An additional disadvantage is that it will collapse under a vacuum. Epoxy coated steel is more resistant to corrosion and offers longer life spans.

- **Cement asbestos -** Cement asbestos (also called AC pipe) is made from Portland cement, long fiber asbestos and silica sand. The pipe is formed on a spinning anvil and cured in an autoclave. Three common classes of pipe are made: Class 100, 150 and 200. These classes refer to the working pressure rating of the pipe. AC pipe is easily corroded, has high hydraulic capabilities and a low shear strength. It is easily damaged by shock loads, either internally or externally.

- **Aluminum -** Aluminum pipe is used in above ground situations as portable pipe. It is often used to pipe water to a traveling irrigation device, such as a center pivot tower or traveling gun hose-reel. Aluminum pipe is sometimes used in solid set systems as well. It is lightweight, very portable, and easily connected. Aluminum pipe does not offer good strength and is easily damaged by machinery or fallen trees. Often, leaks can occur until the distribution system is fully pressurized. Above ground aluminum pipe is not suitable where winter operation is necessary, as freezing causes pipe damage as well as poor function of the sprinkler heads attached to the pipe due to ice clogging.

- **Ductile Cast Iron Pipe (DIP) -** Ductile cast iron pipe is made by injecting magnesium into the cast iron during the molding process. The magnesium alters the shape of the carbon structure of the cast iron, giving the pipe superior beam strength. It will resist high impacts and is more corrosion resistant than gray cast iron. Ductile iron pipe is classed by wall thickness. The common thickness class ranges from 50 through 56; the higher the number, the thicker the wall. However, wall thickness also varies with the size of the pipe. The thickness class needed for a particular condition is based on the internal working pressure, the depth of the cover, the pipe size and the type of bedding condition to be used. Because of its ability to withstand high stress, extreme beam and crush loads, unusual shock, unstable bedding and deep fills, ductile cast iron pipe is one of the few materials that can be used in extreme conditions. Its disadvantages are its weight and its susceptibility of corrosion.

- **PVC -** PVC pipe is made from unplasticized polyvinyl chloride. This material only gained wide acceptance in the wastewater industry when a thicker walled material was developed and an acceptable standard was adopted. The standard that governs most of this thick-walled PVC pipe is called C-900. This distinguishes it from other PVC pipe that has a thinner wall. PVC is manufactured in various sizes and wall thicknesses.

There are three groupings of pipe material commonly used in the wastewater industry.

- **Scheduled Pipe -** First there is the *scheduled* pipe. *Schedule* refers to the thickness of the pipe; a higher number denotes a thicker pipe. The two common schedules are schedule 40 and schedule 80. This material is not normally placed in a trench, but is used as piping in small pump stations and in chlorine stations. The wall thickness, ID, and OD of scheduled pipe are based on steel pipe dimensions. The working pressure will vary from 600 psi for 1/2 inch schedule 40 to 160 psi for 8 inch schedule 40.

- **Pressure Pipe -** Second there is what is called *pressure pipe*. This material is manufactured in iron pipe OD sizes (IPS). The common classifications of this pipe are 160 psi, 200 psi and 315 psi. This material can be joined by either push-on gasket fittings or solvent welds.

- **Class Pipe -** Third, there is *class pipe*, which is manufactured in both iron pipe OD sizes and cast iron OD sizes. There are three classes of this material based on a standard working pressure. The classes are 100, 150, and 200. The wall thickness of the pipe increases as the pipe diameter increases. Class 200 PVC pipe with cast iron pipe outside dimensions is the most common Class pipe used in the wastewater industry.

The primary advantages of PVC pipe are its light weight, the ease with which it can be cut, and its ability to resist corrosion. One of its disadvantages is its inability to withstand high impact and shocks. It is also sensitive to sunlight if stored outside too long and will elongate in high ambient temperatures, making installation difficult. Plastic pipe should not be used in areas where petroleum products may be present. Finally, in cold weather it becomes brittle, requiring special handling.

Fittings

Pipe fittings are joints or connectors between pieces of pipe. Examples are *elbows* that alter the direction of a pipe, *tees* and *crosses* to connect a branch with a main, *plugs* and *caps* to close an end, and *bushings*, diminishers, or reducing sockets to couple two pipes of different dimensions. It is important to note that Schedule PVC fittings do not have the same rating as the pipe.

Pipe *cleanouts* should be used whenever wastewater has a solids content that causes the potential for solids buildup and clogging in piping. Cleanouts are also advised at sharp turns in piping, such as elbows, where water tends to slow down. A pipe cleanout is typically a *wye* fitting (a pipe fitting with three branches positioned in one plane in a pattern of the letter Y) that is installed several feet up-flow from the appropriate area to be cleaned. The “dead end” of the wye is at the ground surface or above for easy access, and is capped off with a threaded plug. This access must be protected from equipment and traffic. The cleanout allows the operator to clean the piping with plumbing snakes, augers, or water pressure cleaners.

Thrust blocking is used in irrigation systems, using moderate to high water pressures to protect the distribution system from damage that could be caused by water pressure. Thrust blocking is used at all points at which water flow either changes direction (such as tees and elbows) or comes to a dead end (ends of laterals or field valves). The thrust block, which is typically a mass of concrete, must lie against natural ground to offer the most protection. Pipe excavation for repair at any of these points is likely to encounter concrete thrust blocks, which must be replaced when replacing pipe or fittings where water changes direction.

Connections

A connection is a collar or coupling that fits over adjacent ends of pipe to be joined, and which, when drawn tight, holds the pipe together either by friction or by mechanical bond. Connections include the following:

- **flange -** a connection made by flanges bolted together; the joint is made water-tight by a gasket placed between the two flanges.
- **mechanical joint -** any form of flexible joint involving lugs and bolts; uses a bell and spigot arrangement. A rubber gasket is placed around the spigot. The gasket is forced into the bell by a metal ring (called a follower ring) that is held to the bell by a series of bolts.
- **bell and spigot** - a form of joint used on pipes, which have an enlarged diameter or bell at one end, and a spigot at the other, which fits into and is laid in the bell. The joint is then made tight by lead, cement, rubber "O-ring, or other jointing compounds or materials.
- **threaded -** a connection made by threading a male end section of pipe or fitting into a female fitting or adapter. With metal threads, pipe compound is

typically required for a waterproof seal. Teflon thread tape may be used on metal or PVC pipe threads.

- **PVC cement -** also called "solvent weld"; uses a special primer and glue to physically mate (connect) pipe and fittings. The glue causes the PVC to bond by a chemical reaction that melts the two pipes, allows them to combine, then cools and solidifies into the banded pipe.

Valves

A valve is a device installed in a pipeline to control the magnitude and direction of the flow. It consists essentially of a shell and a disk or plug fitted to the shell. Valves vary in construction and size, depending upon their function. Some are classified according to their method of operation or design and some are named for the functions they perform. Valves can be operated automatically or manually. Types of valves encountered in a wastewater land application system include the following:

- **gate valve -** typically used as a shut-off valve. A disc in the valve is raised and lowered by a threaded stem or sliding stem to open and close the valve. Gate valves are used in pressure distribution systems to regulate the rate of wastewater flow. Gate valves are designed to operate fully open or fully closed.
- **plug valve** - often used in multiple outlet valves, such as diversion valves. Like a gate valve, a plug valve has an unobstructed flow, yet requires only a 90^{o} turn to open it. The movable control element is a cylindrical or conical plug, in contrast to a flat disk. The valve is turned directly with a key to change the less-than-fully open port.
- **butterfly valve -** has a disc that turns sideways to open the valve. It is a one-quarter turn valve and can be used for throttling relatively clean water. The disk, as it opens or closes, rotates about a spindle supported by the frame of the valve. The valve is opened at a stem. At full opening, the disk is in a position parallel to the axis of the conduit.
- **check valve -** allows wastewater to flow in only one direction. Check valves either have ball or flapper mechanisms that prevent backflow of effluent. A valve provided with a disk hinged on one edge so that it opens in the direction of normal flow and closes with reversal of flow.
- **solenoid valve -** uses a solenoid (an electric coil) to open and close small openings to divert fluid from one side of a diaphragm to the other. When the pressure on top of the diaphragm is equal to the inlet pressure, the valve will remain closed. When pressure is released from on top of the diaphragm, a pump can then open the device. Solenoids can operate small valves or other electrical switches.
- **pressure relief valve -** valve that, when actuated by static pressure above a predetermined level, opens in proportion to the excess above this level and reduces the pressure.
- **air relief valve -** designed to allow the release of air pressure in an irrigation system. Air relief valves are typically installed at the distal ends of long runs of piping, at high elevation points in fields, and at other places where air may be trapped, such as at a field valve or sharp turn in the piping. These valves

have a ball or some mechanism that allows air to escape, but shuts tightly when water pressure enters them. Their purpose is to allow air that is in the piping system to escape when water is being pumped into the system and to help eliminate damage to pipes and sprinklers from excessive air pressure.

- **globe valve** - water is directed through the valve in a specific direction, then is forced to change direction and go through a large orifice, hit a disk and again change direction to exit the valve. This induces head loss and makes it a good throttling device. It has a round, ball-like shell and horizontal disk.
- **bleeder valve -** used for draining a tank, tube, etc.

Irrigation Application Devices (Sprinklers)

Sprinklers, drip emitters, and other devices are used to distribute wastewater to the land application fields. Many people consider the application devices (sprinklers) to be the heart of the irrigation system, but a well designed and properly functioning pumping system is critical to the operation of the sprinklers. However, most operators of wastewater land application systems will spend much of their time dealing with sprinkler management, maintenance, and repair. Sprinkler maintenance and operation is a key component of successfully managing a wastewater land application system.

Many types of irrigation application devices are available. Most are not designed for wastewater application, but some have been adapted for wastewater. Many function well where wastewater is very dilute and has few solids or chemicals. It is beyond the scope of this manual to discuss all types of equipment available. The operator should be familiar with the basic terms describing irrigation equipment and the factors that affect the operation of that equipment. When purchasing irrigation equipment, always notify the dealer that the equipment will be used in a wastewater setting.

Some common types of irrigation application devices (sprinklers) are described below:

- **nozzle -** the part of the sprinkler where the wastewater discharge occurs. Important factors are nozzle type (plastic, brass, taper bore, ring, etc.) and nozzle size at the opening (in inches).
- **full circle sprinkler** - a sprinkler that turns 360 degrees and wets a total circle. These are used in the interior and exterior positions of land application fields.
- **partial circle or partial turn sprinkler -** a special sprinkler that allows the operator to direct discharge to a select portion of the field. Devices such as clips or threaded stops cause the sprinkler to rotate part circle (less than 360 degrees). These are often used to prevent irrigation into buffers, roadways, ditches, or problem areas in the field. One must be aware that using part turn sprinklers, without changing other parameters, such as nozzle size or pressure, results in an increased wastewater application rate. For example, a ¼ turn sprinkler with the same settings as a full turn sprinkler will apply four times as much wastewater per hour to the area it irrigates. Part turn sprinklers must be operated very carefully to avoid ponding and runoff.

- **gun -** usually refers to a large sprinkler with nozzle opening exceeding ½ inch. A gun is usually mounted onto a permanent riser of two-inch pipe size or larger, a traveling gun cart, or the distal end of a center pivot system.
- **rotary head sprinkler** - a sprinkler whose head rotates around the base due to a swinging, spring-loaded impact arm. The water pressure throws the arm to the side; it returns due to the spring, and intercepts the water stream, causing the sprinkler to rotate several degrees. These sprinklers are much more moderately priced than guns.
- micro spray heads - devices that distribute wastewater in a variety of patterns other than the rotary impact sprinkler head described above. Water is deflected via vanes, grooves, wobbling weights, and other devices that allow for wastewater distribution. Usually, these are used with lower pressures (5 to 30 psi), and often are used to reduce wind drift. The length of wastewater throw is limited, thus requiring close spacing.
- drip emitters - installed in flexible (PVC, polyethylene) tubing (hoses). They allow wastewater that is under pressure inside the tubing to be emitted at low pressures. Usually, this type of piping is installed at the ground surface or slightly under the ground surface to provide water uptake by plant roots. The drip emitter consists of a labyrinth inside the hose that allows for pressure drop as the wastewater is emitted. The orifice size is about 1/16 to 1/8 of an inch and distributes less than one gallon per minute.

Solid Set Irrigation Equipment

Solid set or stationary systems for the land application of wastewater are usually permanent installations (lateral lines are PVC pipes permanently installed below ground). One of the main advantages of stationary sprinkler systems is that these systems are well suited to irregularly shaped fields. Thus, it is difficult to give a standard layout, but there are some common features between systems.

Sprinkler spacing is based on nozzle flow rate and the desired application rate. To provide proper overlap, sprinkler spacings are normally 50 to 65 percent of the sprinkler wetted diameter, or in the range of 80 feet by 80 feet. Other spacings can be used and some systems are designed to use gun sprinklers (higher volume) on wider spacings. A typical layout for a permanent irrigation system is shown in Figure 6-3.

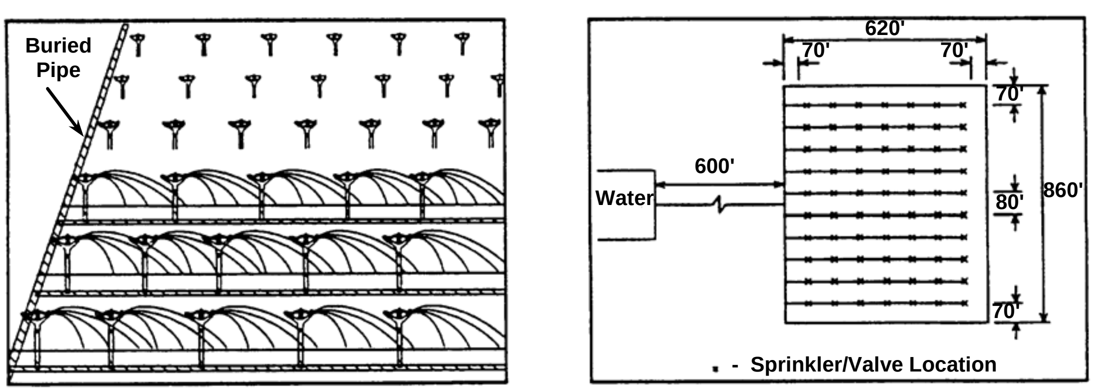

Figure 6-3. Schematic layout of a typical solid set irrigation system.

The minimum recommended nozzle size for wastewater is ¼ inch. Typical operating pressure at the sprinkler is 25 to 60 psi. Sprinklers can operate full or partial circle. The system should be zoned (any sprinklers operated at one time constitutes one zone) so that all sprinklers are operating on about the same amount of rotation to achieve uniform application. Gun sprinklers typically have higher application rates; therefore, adjacent guns should not be operated at the same time (referred to as "head to head"). Most permanent systems use Class 160 PVC plastic pipe for mains, submains, and laterals and either 1-inch galvanized steel or Schedule 40 or 80 PVC risers near the ground surface where an aluminum quick coupling riser valve is installed (Figure 6-4). In grazing conditions, all risers must be protected (stabilized) if left in the field with animals.

The advantages of fixed irrigation equipment include the following:

- flexible irrigation rates
- suitability for irregularly shaped fields
- suitability for tree crops

Disadvantages of fixed irrigation equipment include the following:

- high capital costs
- limited use for row crops

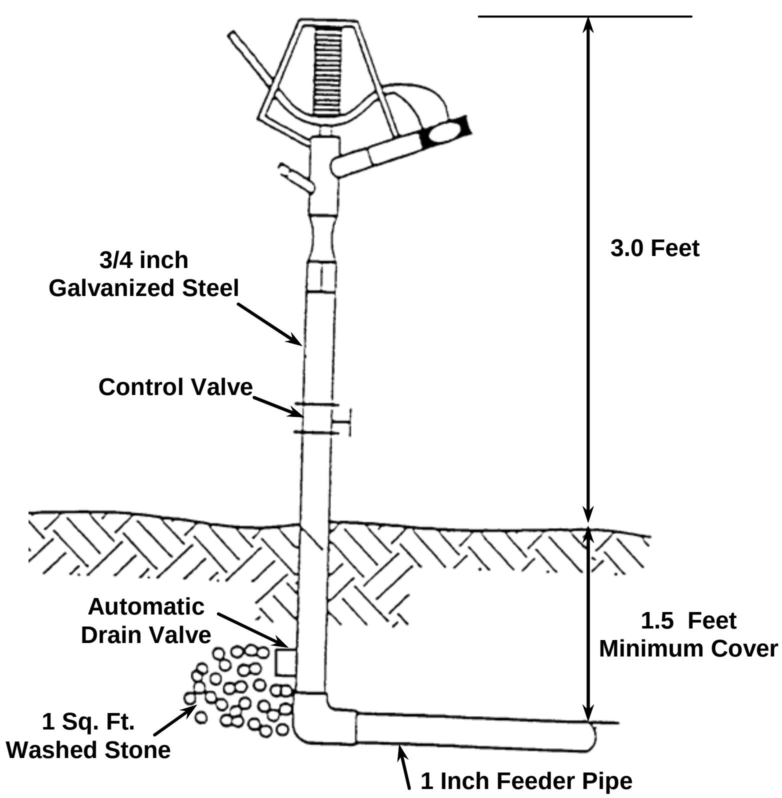

Figure 6-4. Typical spray head for a fixed system.

Mobile Irrigation Equipment

Mobile, or *traveling*, sprinkler systems are either cable-tow or hose-drag travelers, center pivot, or linear-move systems.

Travelers

The cable-tow traveler consists of a single-gun sprinkler mounted on a trailer with water being supplied through a flexible, synthetic fabric, rubber- or PVC-coated hose. A steel cable is used to guide the gun cart.

The hose-drag traveler consists of a hose drum, a medium-density polyethylene (PE) hose, and a gun-type sprinkler. The hose drum is mounted on a multi-wheel trailer or wagon. The gun sprinkler is mounted on a wheel or sled type cart referred to as the *gun cart*. Normally, only one gun is mounted on the gun cart. The hose supplies wastewater to the gun sprinkler and also pulls the gun cart toward the drum (Figure 6-5).

Figure 6-5. Hard hose traveler showing reel and gun cart.

The distance between adjacent pulls is referred to as the *lane spacing*. To provide proper overlap, the lane spacing is normally 70 to 80 percent of the gun wetted diameter. Operating pressures range from 80 to 150 psi. Like stationary sprinklers, traveling guns can operate full or partial circle. A typical layout for a hard-hose traveler irrigation system is shown in Figure 6-6.

The hose drum is rotated by a water turbine, water piston, water bellows, or by an internal combustion engine. Regardless of the drive mechanism, the system should be equipped with speed compensation so that the sprinkler cart travels at a uniform speed from the beginning of the pull until the hose is fully wound onto the hose reel. If the solids content of the wastewater exceeds one percent, an engine drive should be used.

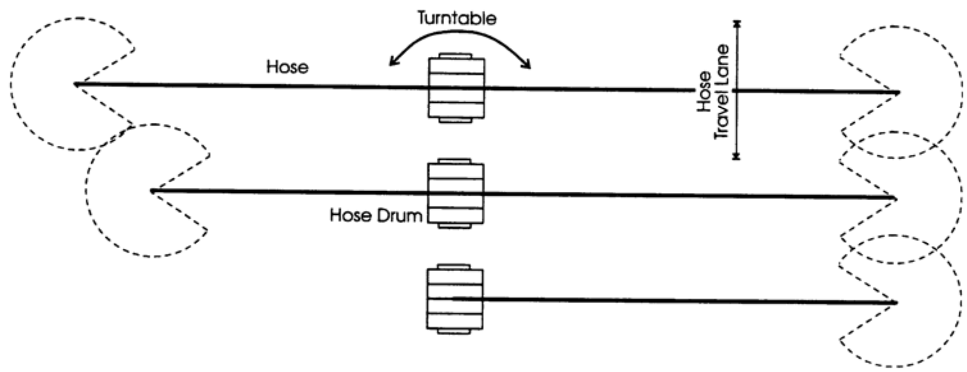

Figure 6-6. Schematic layout of a hose-drag traveler. Travel lanes are 100 to 300 feet apart, depending on sprinkler capacity and diameter coverage.

Nozzle sizes on gun-type travelers range from 1/2 to 2 inches in diameter. There are three types of nozzles: *taper bore*, *ring* or *taper ring*. The ring nozzle provides better breakup of the wastewater stream, resulting in smaller droplets with less impact energy (less soil compaction) and providing better application uniformity throughout the wetted radius. But, for the same operating pressure and flow rate, the taper bore nozzle throws water about five percent further than the ring nozzle, i.e. the wetted diameter of a taper bore nozzle is five percent wider than the wetted diameter of a ring nozzle. This results in about a ten percent larger wetted area.

A gun sprinkler with a taper bore nozzle is normally sold with only one size nozzle, whereas a ring nozzle is often provided with a set of rings ranging in size from 1/2 to 2 inches in diameter. This allows the operator flexibility to adjust flow rate and diameter of throw without sacrificing application uniformity.

Furthermore, on water drive systems, the speed compensation mechanism is affected by flow rate. There is a minimum threshold flow required for proper operation of the speed compensation mechanism. If the flow drops below the threshold, the travel speed becomes disproportionately slower, resulting in excessive application even though a smaller nozzle is being used. System operators should be knowledgeable of the relationships between nozzle size, flow rate, wetted diameter, and travel speed before interchanging different nozzle sizes.

Advantages of traveling irrigation systems include the following:

- lower capital costs
- adjustable speed with no interruption of irrigation

Disadvantages of traveling irrigation systems include the following:

- high application rates on large units (0.3 to 1.0 inch per hour)
- potential runoff and ponding from traveler lanes
- high operating costs (energy)
- requires two people to operate
- limited use on forested sites (can result in debarking unless diffusers are used)

Center Pivots and Linear Move Systems

The use of center-pivot systems for wastewater irrigation is increasing. Center pivots are available in both fixed-pivot point and towable machines. They are available in size from single tower machines that cover around 10 acres to multi-tower machines that can cover several hundred acres. Center pivots use either rotary sprinklers, small guns, or spray nozzles. Operating pressures range from 25 to 60 psi. Drop-type spray nozzles offer the advantage of applying wastewater close to the ground at low pressure, which results in less wastewater drift due to wind.

A center pivot device applies wastewater along an elevated distribution pipe that is anchored at one end. Wastewater is supplied at the anchored end and distributed from sprinkler heads mounted to the distribution pipe. The unit is driven by an electrical motor mounted at the fixed end. When properly designed and operated, the application rate of each sprinkler head increases with its distance from the fixed center, so that there is uniform application of water as the pivot moves in a circular motion (Figure 6-7 and Figure 6-8).

Figure 6-7. Center pivot system.

Linear-move systems are similar to center pivot systems, except that neither end of the distribution pipe is anchored, and travel is in a straight line. Drives at each end move the distribution pipe across the wastewater land application field. Wastewater is supplied through a feeder hose to one end of the distribution pipe. Depending on the type of sprinkler used, operating pressure ranges from 10 to 50 psi. Low pressure systems reduce drift at the expense of higher application rates and greater potential for runoff.

Figure 6-8. Center pivot control panel.

Advantages of center pivot and linear move systems include the following:

- excellent irrigation control (programmable)
- wide range in application rates (0.1 to 1.0 inch per hour)
- low operating costs (energy, people)
- bad weather options (rain, wind)

Disadvantages of center pivot and linear move systems include the following:

- high capital costs
- center pivots fixed to one side (towable pivots available)
- wheel tracks are potential source of runoff and ponding

Operational Issues

By understanding the components of the irrigation system, their layout and installation, and by using monitoring devices, a wastewater land application operator can effectively operate the wastewater irrigation system. Troubleshooting problems early can also prevent significant and expensive equipment problems and possible negative impacts to the environment.

An operator should be familiar with all components that make up a land application facility, including the irrigation system. This is most easily done by maintaining a set of approved *as-built* plans for the facility, because design plans do not always reflect what was actually installed during construction.

The as-built plans should provide sufficient detail, such that the operator can determine the location, size, and type of all pipes, valves, and fittings. This will allow the operator to perform quick service and repair, and to keep spare parts on hand. If as-built plans are not on-site, a set may be obtained from the design engineer for the facility.

If both wastewater and supplemental irrigation water are applied to the land application fields, determine if the supplemental irrigation water supply is directly connected to the wastewater distribution system. If so, a DEQ-approved backflow prevention device must be installed to protect the quality of the fresh irrigation well water supply. If the supplemental irrigation water comes from two sources, a backlow preventation device should also be installed between an irrigation wellwll and surface water delivery system in ditches or canals.

The operator must be familiar with pump discharge rates and the factors that affect discharge rates as described earlier. Knowledge of operating pressures in the field is crucial to understanding and evaluating wastewater application flow rates and system efficiency. Pressure is often measured at the pump, with the assumption that the same pressure exists throughout the distribution system. It is valuable to measure pressure at several locations. Measuring pressure at the discharge point (sprinkler or gun) provides the most information about the actual rate of wastewater application.

Most guns have a fitting where a pressure gauge can be easily mounted. Rotary impact sprinklers can be fitted with a pressure gauge by installing a tee in the sprinkler riser. On an irrigation system or zone with multiple sprinklers, several pressure readings across the field give the best picture. However, at least one reading near mid-field and one near sprinklers installed at higher elevations provide valuable pressure information for the system. The pressure at the sprinkler head dictates the flow rate (gallons per minute) through that sprinkler. Significant elevation changes within one field or zone can result in higher discharge pressures and rates in the lower portions of the field.

Knowledge of pump pressure and field pressure can help an operator determine if pumps are running efficiently. Gathering baseline data can also help determine when pipes are beginning to clog. Blockages, as well as broken or separated pipes, can cause pressure reductions in the distribution system. These problems often result in extremely wet areas that will be obvious to the operator. Wet and soggy areas near valves and fittings may indicate that the pipe has been damaged or improperly installed, such that leaks are causing the soil in the area to remain saturated.

Close monitoring of wastewater pumping rates by use of flow meters or pump operating data will help with operational and maintenance decisions at the facility. Such things as pump, piping, and sprinkler wear can be predicted with accurate flow records. These records can also help the operator determine if infiltration and inflow from the collection system are contributing to the wastewater stream. Accurate flow monitoring is important for compliance with state record keeping requirements, and may indicate when a system expansion is necessary.

If actual applied wastewater flows exceed the irrigation system design flow, then a detailed examination of the pumping and irrigation systems should be conducted and necessary steps should be taken to maintain compliance with the wastewater land application permit. Pump monitoring records, such as pump run time and number of pump cycles, can be used to monitor pump efficiency and proper working of float switches or relays. Following an inspection and maintenance schedule to identify and replace worn components will help a system to operate at system to operate at its design flow.

In summary, an operator should maintain detailed records of all equipment and operational parameters at the facility. In conjunction with a detailed set of as-built plans, operational and maintenance decisions can be made to provide long equipment life and efficient overall system operation. Additional information regarding the operation and maintenance of land application equipment is presented in Section 9.

References:

State of North Carolina, 2001. Spray Irrigation System Operators Training Manual.

State of Idaho, Department of Environmental Quality, 2005. Wastewater Land Application Permit Rules (IDAPA 58.01.17).

State of Idaho, Department of Environmental Quality. Guidance for Land Application of Municipal and Industrial Wastewater - October 2004.